ENGINEERING CASE LIBRARY

ECL 159

JUMPING A DERRICK

A Case Study
in
Construction Engineering

by

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JUMPING A DERRICK

The Erection Department of the Bethlehem Steel Corporation bids on supplying and joining the columns and beams for a variety of steel structures. If the bid is accepted, the structural members are fabricated at a central shop and shipped to the site. There the steel is erected in accordance with the architect's specifications following an erection sequence planned by an office engineer.

On the job, the steel company is represented by a field engineer who is responsible for technical aspects of the project and who provides liaison with the erection crew and the building inspectors. Because the job seldom proceeds exactly as planned, the field engineer is frequently called on to approve slight modifications in plan or procedure. In this case, he was asked to approve "jumping" the guy derrick up two floors before the welders had completed their work below.

Dan Jeffrey,* field engineer for the Bethlehem Steel Corporation, stood on temporary planking at what would become the 20th floor of a 26-story office building. The Southern California sun was bright, the air was unusually clear, and it was obvious that he felt good. The previous week they had lost one day because the wind was too strong for safe maneuvering of the 85-foot derrick and another day that was too rainy for the welders; but this week construction was going well and with luck they would get back on schedule.

This was his first field assignment after six months of varied office experience as a technical trainee. He had graduated with a BS in the Construction Option of Civil Engineering and fortunately, he said, he had taken some extra courses in structures. As he looked at the solid steel skeleton two floors below and the partially welded framework immediately below, he could visualize the role each column and beam would play in the completed building.

At the moment he was mentally checking his earlier recommendation to Russ Spayd, the erection superintendent, about steel storage on the next floor. To minimize truck delay and ground-level storage, steel usually is lifted by derrick directly from the truck to the top completed

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*Fictitious names are used in this study.

Derrick at twentieth floor of City National Bank project

floor and "landed" there for temporary storage. Because the strength of the structure develops as welds are completed, the disposition of a truckload of heavy members may be critical. One of the field engineer's duties is figuring where steel should be landed and how much can be safely stored at any stage of erection.

ERECTION PROCEDURE

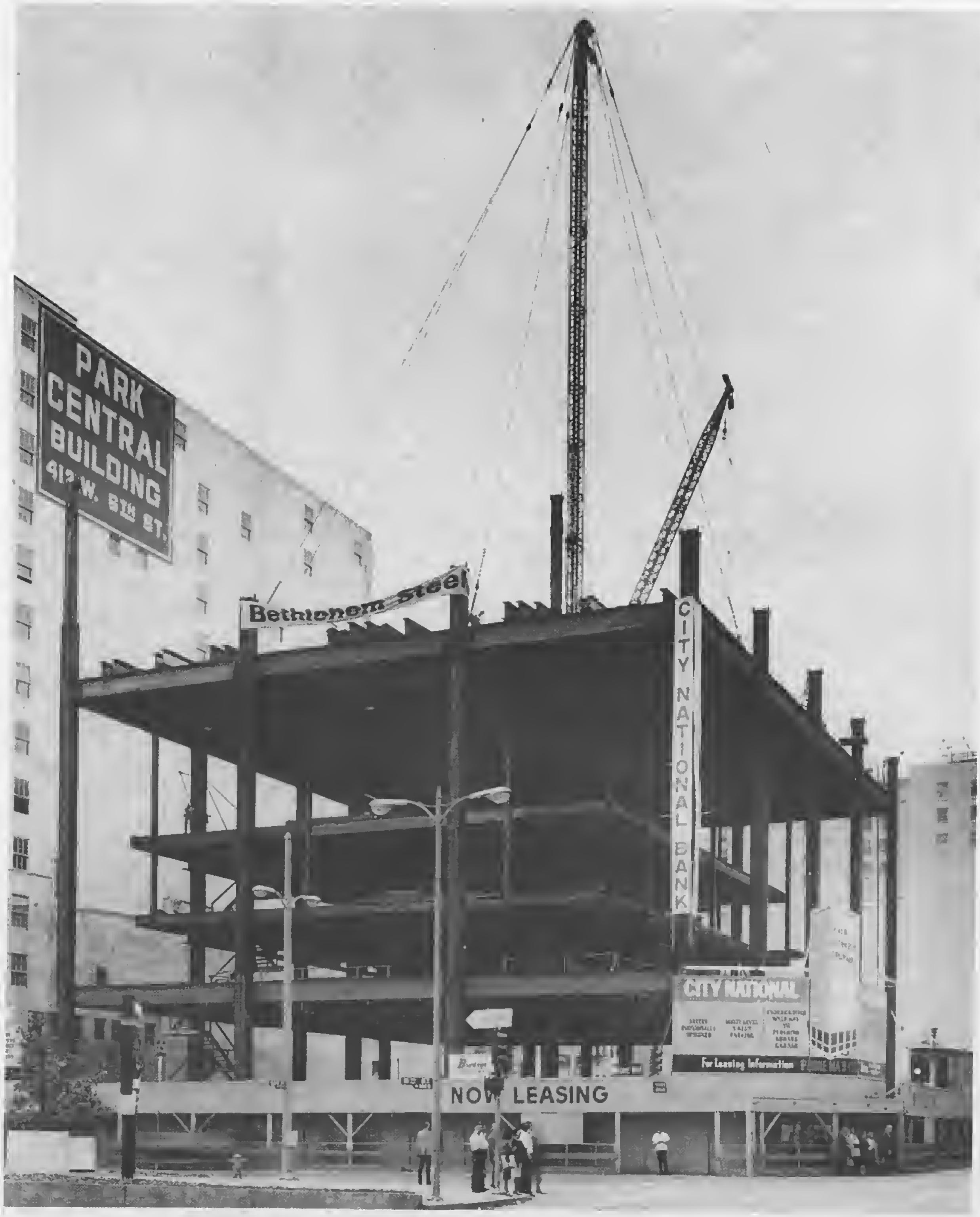
After the steel is landed, the bundles are "shaken out" and the pieces are distributed to their approximate final locations. Typically the columns are two stories high and the building is erected two floors at a time by the "raising gang." The outside and rear columns (away from the unloading area) are placed first. (See Exhibit 1.) The "hooker on" attaches the "hickey" to the column, the "bellman" signals the hoist operator (on the ground) to raise the load, and the "swingman" rotates the boom to the proper direction. The bellman signals "lower the boom and load," the piece is guided into place by the "tagline man," and "connectors" insert two erection bolts in each end, using drift pins to align the holes if necessary. The "fill-in" of the perimeter and floor beams, and the remaining columns, proceeds in accordance with the sequence shown on the erection plans.

A typical steel erection crew would include: a superintendent, a timekeeper (of men and equipment), a field engineer, a hoist operator, a compressor operator, a raising gang (foreman + 6 men), a plumbing crew (foreman + 3 men), a welding crew (foreman + 10 to 15 welders), and a bolt-up gang (foreman + 4 to 8 connectors). At around $6 an hour average, a 30-man crew represents direct and indirect labor costs of nearly $2,000 per day; accurate scheduling and skillful timing are important.

PLUMBING

Over the roar of the generators and the stuttering of the electric arcs, Dan Jeffrey heard his name shouted by the plumbing foreman. As soon as each section is erected, the plumbing crew attaches cables with turnbuckles to each column. This had been done and the foreman was ready to "plumb" the columns, with the help of the field engineer.

Jeffrey caught the open-air construction elevator on its



Derrick at fourth floor of City National Bank project

next trip down and took his transit to the parking lot across the street. While he set up over an established point, he explained what he was doing. "First I sight on a reference point on the building behind our project. Then I sight on the target held by the plumbing foreman. It's about 3 inches out of line so I wave my right hand and they tighten the turnbuckles to pull the column into line. The allowable tolerance here is 1 inch toward or 2 inches away from the building line. This is fairly easy to maintain, but I still remember how shook up I was when I carefully plumbed a section one morning and found it out of line that afternoon. It was a sunny day and the uneven expansion of the beams in sun and shade made me look sloppy. Since then I've learned to take this into consideration."

WORKING CONDITIONS

Taking advantage of the relative quiet at ground level, the field engineer went on to say: "I really like my job - being out of doors and working with people. Also I like to be where the action is; I like the noise and heavy equipment. I like to be 20 stories up and watch the raising gang swing a 6-ton steel column into place. I'm getting so I can walk on a 14-inch wide flange, when I have to, and looking down doesn't panic me any more.

"Another thing I like is the teamwork and the steady progress toward acheivement. The other engineers I talk with all like the feeling of starting with a vacant lot and seeing a completed structure. Every completed building is a pretty solid and quite visible demonstration of what a bunch of men can build."

WELDING

As soon as the section is plumbed and the connections are "fitted up," the welders can strike their arcs and start welding the permanent joints. (The pin-up bolts provide only enough strength to hold the members in place for welding. In fitting up, the gap to be filled with weld is made uniform by slightly twisting the column or beam.) In 10 to 15 passes, the welder builds up a homogeneous joint of low carbon steel. (See Exhibit 2.) As each completed joint cools it contracts, and the welding shrinkage of 1/8 inch or so per joint must be allowed for in the design.

"Approximately 30 percent of the welds are tested ultrasonically by the welding inspector," Jeffrey explained as he left the elevator at the 18th floor. "Any porosity or cracks or slag inclusions would weaken the joint. We had some trouble with porosity early in the project, but less than one joint in twenty shows any defect now. Any weld that fails to pass inspection has to be burned out and done over. You notice that every joint carries the welder's mark."

Just then the superintendent came up and said: "Say, you college hotshot, I'm ready to go. Can I jump this blankety-blank derrick or do I have to let eight good men sit around all afternoon? We're already two days behind schedule and I don't want to take any more gas from the head office."

When the raising gang has finished placing all columns and filling in all beams in a 2-story section, the guy derrick is "jumped" up two floors. For example, the 19th and 20th floors were erected with the derrick on the 18th floor. The derrick (Exhibit 3) consists of an 85-foot vertical mast held by eight guy wires and a 75-foot boom pivoted near the base of the mast. The base of the mast can be rotated by the swing gears. The derrick is supported by two "jumping beams" (provided by the erector), which rest on the "carrying beams," selected portions of the structure.

In anticipation of the superintendent's request, Jeffrey had already checked with the welding foreman. He learned that the welders were behind but that they hoped to start tomorrow on the central section that would support the derrick in the next stage. This section must be strong enough to support the derrick, the guy wires, the jumping beams, and the weight of the carrying beams themselves, plus any live loads.

On the way back down to the construction shack, the field engineer explained the ingenious procedure for jumping the derrick. "First, the boom is raised to a vertical position, unpinned from the mast, moved about 10 feet horizontally, turned 180 degrees, and guyed with four temporary guys. Then, the boom is used as a temporary mast or "gin pole" to raise the mast and footblock vertically through two floors to the new position. With the mast in its new position (with footblock on jumping beams) and securely guyed, the boom is turned, hoisted two floors, and pinned to the mast again."

THE PROBLEM

Spreading out the 20th floor erection plan (Exhibit 1), he explained his problem. "We're using a Type AAA guy derrick (Exhibit 3) supported on two 14WF119 jumping beams. The jumping beams are laid across the carrying beams designated 109E. Right now the 36WF160 carrying beams are held in place by two high-strength pin-up bolts at each end. At the fabrication shop, 30-inch sections of 5/16" angle are welded to the column using three 2-inch long fillet welds (Exhibit 2). The beams are bolted to these angles during erection and then the beams are field-welded to the columns."

"The superintendent wants to jump the derrick immediately but I'm not sure it's safe because the welding is pretty far behind. Maybe we could get one welder up there right away and provide enough strength to allow the superintendent to go ahead this afternoon. Before I stick my neck out, I think I'd better take a few minutes and check it out."

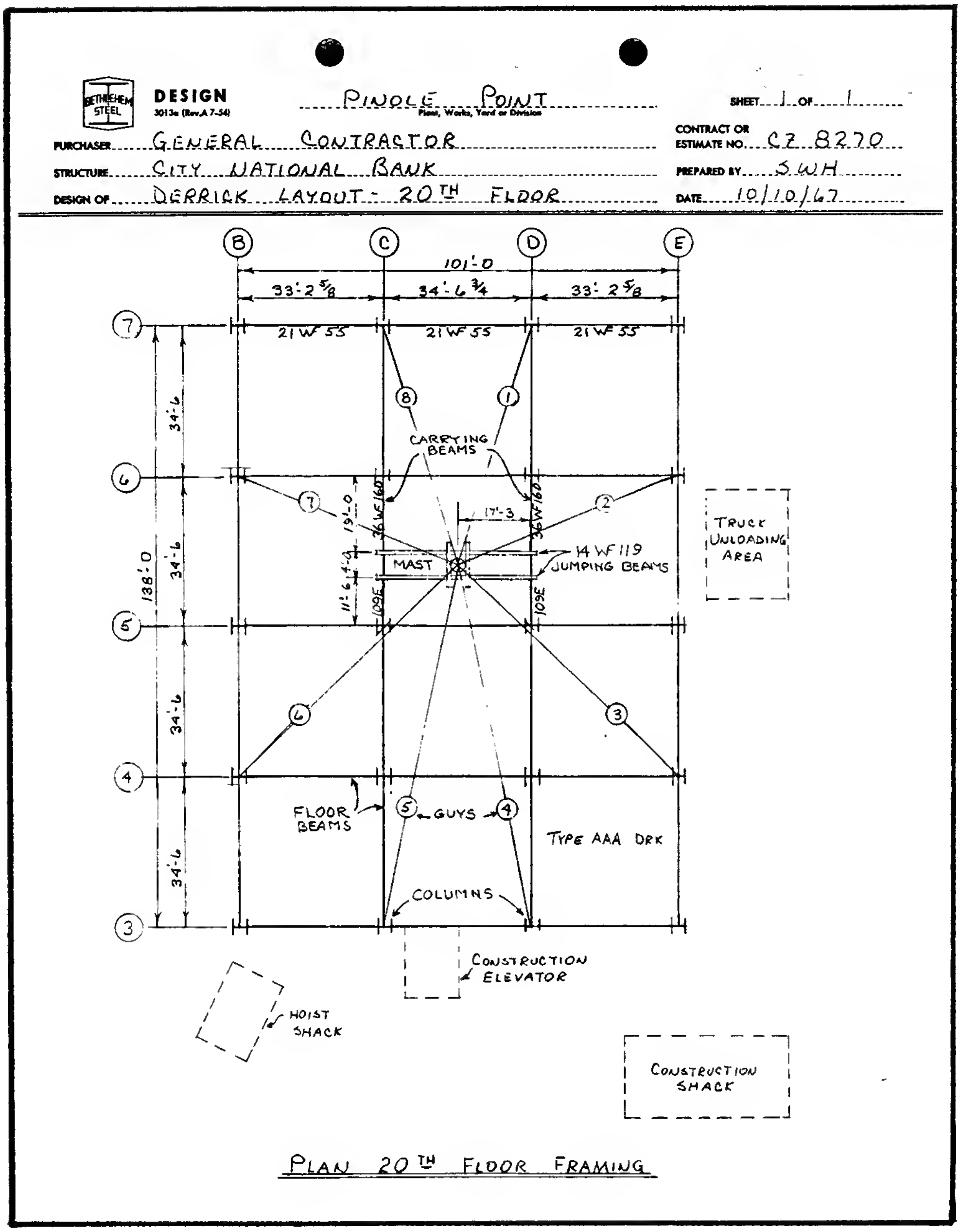

DESIGN
PINOLE POINT
SHEET 1 OF 1
PURCHASER GENERAL CONTRACTOR
CONTRACT OR ESTIMATE NO. CZ 8270
STRUCTURE CITY NATIONAL BANK
PREPARED BY SWH
DESIGN OF DERRICK LAYOUT - 20TH FLOOR
DATE 10/10/67
101'-0
33'-2 5/8
34'-6 3/4
33'-2 5/8
21 WF 55
CARRYING BEAMS
17'-3
14 WF 119 JUMPING BEAMS
MAST
36 WF 160
TRUCK UNLOADING AREA
138'-0
34'-6
FLOOR BEAMS
GUYS
TYPE AAA DRK
COLUMNS
CONSTRUCTION ELEVATOR
HOIST SHACK
CONSTRUCTION SHACK
PLAN 20TH FLOOR FRAMING

EXHIBIT 1

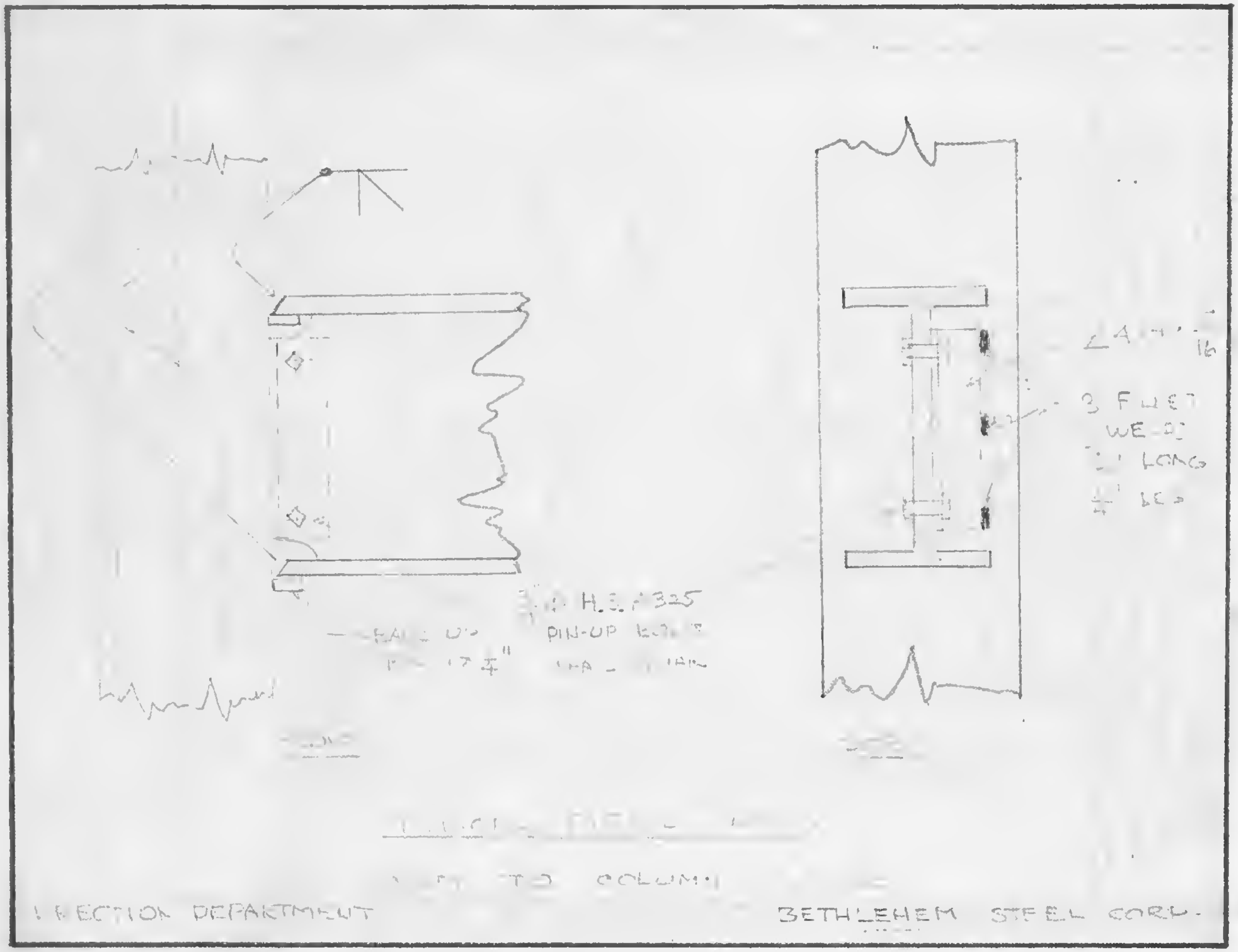

PIN-UP BOLTS
TO COLUMN
ERECTION DEPARTMENT
BETHLEHEM STEEL CORP.

EXHIBIT 2

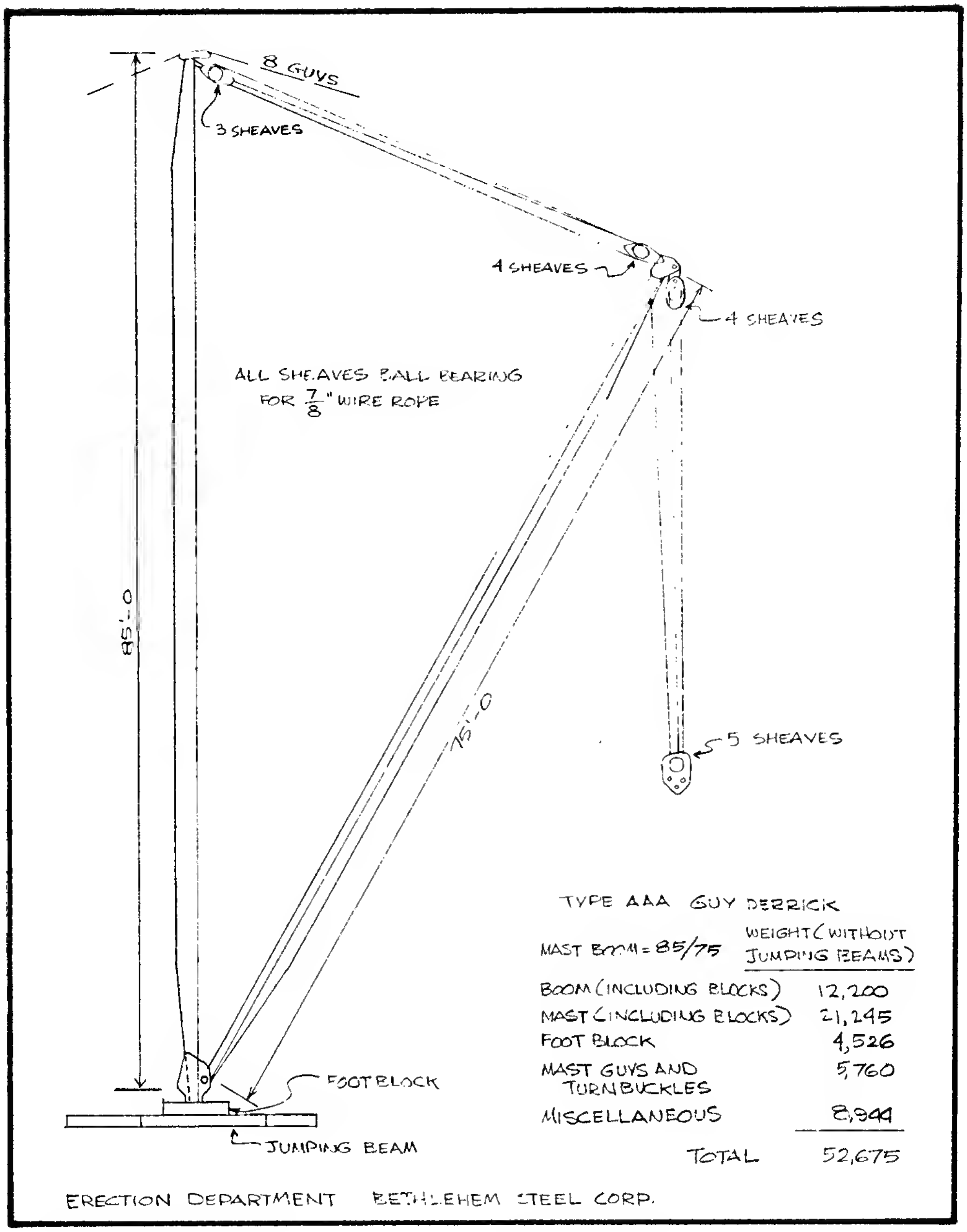

8 GUYS
3 SHEAVES
4 SHEAVES
4 SHEAVES
ALL SHEAVES BALL BEARING FOR 7/8" WIRE ROPE
85'-0
75'-0
5 SHEAVES
FOOT BLOCK
JUMPING BEAM
TYPE AAA GUY DERRICK
MAST BOOM = 85/75
WEIGHT (WITHOUT JUMPING BEAMS)
BOOM (INCLUDING BLOCKS) 12,200
MAST (INCLUDING BLOCKS) 21,245
FOOT BLOCK 4,526
MAST GUYS AND TURNBUCKLES 5,760
MISCELLANEOUS 8,944
TOTAL 52,675
ERECTION DEPARTMENT BETHLEHEM STEEL CORP.

EXHIBIT 3

5/8-3/4-7/8 RIVETS AND THREADED FASTENERS

Shear

Allowable loads in kips

Power Driven Shop and Field Rivets						
Diam. — Area	5/8 in. — .3068 sq. in.		3/4 in. — .4418 sq. in.		7/8 in. — .6013 sq. in.	
ASTM Designation	A141	A195 A406	A141	A195 A406	A141	A195 A406
Shear F_v, ksi	15	20	15	20	15	20
Single Shear, kips	4.60	6.14	6.63	8.84	9.02	12.03
Double Shear, kips	9.20	12.27	13.25	17.67	18.04	24.05

Unfinished Bolts, ASTM A307, and Threaded Parts of ASTM A7 and A373 Material			
Diam. — Area	5/8 in. — .3068 sq. in.	3/4 in. — .4418 sq. in.	7/8 in. — .6013 sq. in.
ASTM Designation	A307, A7, A373	A307, A7, A373	A307, A7, A373
Shear F_v, ksi	10	10	10
Single Shear, kips	3.07	4.42	6.01
Double Shear, kips	6.14	8.84	12.03

High Strength Bolts in Friction Type Connections and in Bearing Type Connections with Threads in Shear Planes						
Diam. — Area	5/8 in. — .3068 sq. in.		3/4 in. — .4418 sq. in.		7/8 in. — .6013 sq. in.	
ASTM Designation	A325	A354 Gr. BC	A325	A354 Gr. BC	A325	A354 Gr. BC
Shear F_v, ksi	15	20	15	20	15	20
Single Shear, kips	4.60	6.14	6.63	8.84	9.02	12.03
Double Shear, kips	9.20	12.27	13.25	17.67	18.04	24.05

High Strength Bolts in Bearing Type Connections with Threads Excluded from Shear Planes						
Diam. — Area	5/8 in. — .3068 sq. in.		3/4 in. — .4418 sq. in.		7/8 in. — .6013 sq. in.	
ASTM Designation	A325	A354 Gr. BC	A325	A354 Gr. BC	A325	A354 Gr. BC
Shear F_v, ksi	22	24	22	24	22	24
Single Shear, kips	6.75	7.36	9.72	10.60	13.23	14.43
Double Shear, kips	13.50	14.73	19.44	21.21	26.46	28.86

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

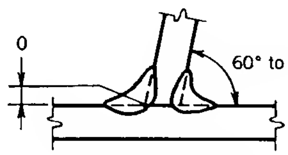
EXHIBIT 4. Excerpt from Manual of Steel Construction

WELDED JOINTS

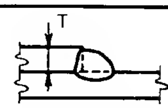
Details of fillet welds

For Manual Shielded Metal-Arc and Submerged Arc Welding

FILLET WELDS

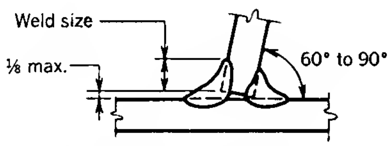


SKEWED TEE JOINT

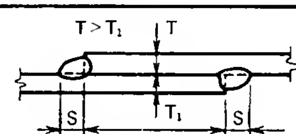


For T less than 1/4: Max. Eff. fillet size = T
For T 1/4 or over: Max. Eff. fillet size = T − 1/16

[a] EDGE FILLET



SKEWED TEE JOINT



5 T_1 min.
not less than 1"
S = as required

DOUBLE FILLET LAP JOINT

[a] For Max. weld size = T when T > 1/4, see AISC Specification, Sect. 1.17.5.

ENGINEER'S CALCULATIONS:

Fillet weld strength

Weld size (in.)	Allowable load per linear in. (lb)
1/8	1,200
3/16	1,800
1/4	2,400
5/16	3,000
3/8	3,600
7/16	4,200
1/2	4,800

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

EXHIBIT 5. Excerpt from Manual of Steel Construction

INSTRUCTOR'S NOTE

Jumping a Derrick

On October 6, 1967, several months after this case was prepared, the Baton Rouge, La. STATE TIMES carried this story:

* * * * * *

CRANE ATOP BANK BUILDING TOPPLES

Two men were killed and five others injured when a derrick collapsed atop the Louisiana National Bank building being constructed on Florida Street, according to unofficial but reliable reports.

Workers at the base of the building said the crane on the 20th floor was in the process of being "jumped", or moved up one more floor to continue work. Workmen had jacked the orange-colored crane up to the next floor and had just "dogged it off" - anchored it - when a loud snap was heard and the crane began falling back into the well beneath it. The derrick toppled over and a portion of the boom fell across the edge of the building facing south on Florida Street.

* * *

This "critical instant" case presents the background of a situation requiring action; the field engineer on a construction job is asked to approve jumping the derrick before welding is completed. The student has available information on the weights and strengths of structural elements. By applying elementary principles of statics and strength of materials, he can make the calculations necessary for a decision.

OBJECTIVES

Possible objectives in the use of this case at the freshman level include providing:

- A description of one aspect of construction engineering.
- An introduction to the duties of a junior civil engineer.
- Motivation for studying mechanics and materials.
- Practice in solving elementary engineering problems.
- An illustration of decision making in the real world.

In the following discussion, the emphasis is on problem solving in a real situation, taking into account economic and safety factors and the necessity for making simplifying assumptions.

POSSIBLE ASSIGNMENT

Part I (before class discussion)

A. Read ECL 159, JUMPING A DERRICK, and be prepared to explain the following terms: jumping, bundle, drift pin, hooker on, bellman, swingman, plumbing, transit, wide flange, 14WF119, fitting up, welding passes, porosity, carrying beam, dead and live load, footblock, pin-up bolt, hoist shack, sheave, allowable load, kip, shear plane, and fillet weld as used in the case.

B. Write a one-page description of the case identifying the problem, indicating the nature of the answer, listing additional information needed, and outlining a possible solution.

Part II (after class discussion)

Following the procedure, solve the problem facing the field engineer and state the action you would take in his place.

CLASS DISCUSSION

A class period could be devoted to getting student to answer such questions as:

- Which are the important factors?
- What is the central problem in this case?
- What is the nature of the appropriate answer?
- What approach should be used?
- What additional information is needed?
- What simplifying assumptions can be made?
- How could you solve the simplified problem?
- How could you check your solution?

During the discussion, students should receive help in reading the plans, in making assumptions, in drawing a free-body diagram, in applying the principles of statics, in using the data in the AISC Manual, and in drawing conclusions. The following comments indicate the method of approach for which the students ought to be prepared.

PROBLEM SOLUTION

Preliminary Analysis

To answer the superintendent's request for permission to jump the derrick immediately, the field engineer must decide if the erection connections will hold the load of the derrick and accessories. If not, he must decide what action to take to strengthen the connections.

The critical elements are the pin-up bolts and the intermittent welds on the erection angles. Each must be examined separately

and if either is inadequate, corrective action must be taken.

This is a technical problem that can be analyzed using the principles of statics. The predicted stresses or loads can be compared to the allowable values pyblished by the American Institute of Steel Construction (AISC). These are conservative values based on 40 to 60% of yield strength.* High precision is not required and approximate calculations are satisfactory, therefore simplifying assumptions can be made. The important factors are: the weight of the derrick and accessories, the dimensions of the carrying beams, the position of the jumping beams, the dimensions and allowable stresses in the bolts and welds. All this information is available.

Statement

The overall problem can be broken down into three specific questions:

1. Neglecting moment** and assuming the bolts are in simple shear, is the force on the bolts within the allowable load?

2. Neglecting moment and assuming the shop welds are in simple shear, is the force on the welds within the allowable load?

3. If the answer to either 1 or 2 is "No", what corrective action should be taken?

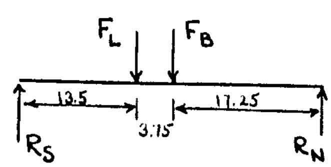
Solution

1. From the Guy Derrick spec sheet (Exhibit 3), the load on each carrying beam is:

Derrick	52,675 x 1/2 =	26,340
Jumping beams	2 x 119 lb/ft x 35 ft x 1/2 =	4,170
	Total = F_L =	30,510 lb

The weight of each carrying beam is:

F_B = 160 lb/ft x 34.5 ft = 5520 lb.



These forces may be considered to be concentrated as shown along with the reactions at the North (top of sheet) and South ends.

*These conservative "allowable" values incorporate a "factor of safety"; permanent structures (supporting people) may be safely designed using the published values.

**The bolts fit loosely in the pre-drilled holes and the moment developed in small deflections is negligible.

Since the beam is in equilibrium,

$\Sigma M_S = 0 = 30{,}510 \times 13.5 + 5520 \times 17.5 - R_N \times 34.5$ or $R_N = 14{,}680$ lb

$\Sigma M_N = 0 = R_S \times 34.5 - 30{,}510 \times 21 - 5520 \times 17.25$ or $R_S = 21{,}350$ lb

From the AISC Manual of Steel Construction (Exhibit 4), the "allowable load" on a 3/4" A325 high-strength bolt in a bearing type connection with threads excluded from shear planes is 9.72 kips (kilopounds) or 9,720 lb.

Two bolts can support 2 X 9,720 = 19,440 lb on a permanent basis with a liberal safety factor. This is within 10% of the larger predicted load (at R_S), and therefore the answer to Question 1 is "No, but it is safe for temporary construction."

2. From the Fillet Weld Strength Table (Exhibit 5), a 1/4" fillet weld supports an allowable load of 2400 lb/lineal inch. Three 2-inch welds provide a strength of 3x2x2400 = 14,400 lb. Since R_N = 14,680 = 14,400 lb., the North connection is OK. Since R_S = 21,350 > 14,400 lb. by 50%, the South connection is inadequate and the answer to Question 2 is: "No".

3. To bring the load at the South connection within the allowable limit, add welding to the angle-column joint.

Additional strength required $\cong$ 21,400 - 14,400 = 7,000 lb.

Additional length required = 7000/2400 $\cong$ 3 in.

Check

As a simple numerical check on the reaction calculations, the sum of the four reactions should equal the total weight of the derrick + jumping beams + carrying beams.

$\Sigma R = 2R_N + 2R_S = 2 \times 14{,}680 + 2 \times 21{,}350 = 72{,}060$ lb

$\Sigma W = W_D + 2W_J + 2W_C = 52{,}675 + 2 \times 4170 + 2 \times 5520 = 72{,}055$ lb.

As a quick check on the weld addition, the total weld strength is (3x2 + 3 in.) 2400 lb/in. = 21,600 lb > R_S = 21,350 lb.

Action

An approximate analysis of the bolted structure indicates that it is not strong enough to permit jumping the derrick immediately. The addition of about 3 in. of weld on the flanges at the South end of each carrying beam will provide sufficient additional strength

Ask the foreman to put one welder on this immediately and inform the superintendent that he can start the jumping operation, but point out that the auxiliary welding must be completed before the derrick is assembled on the top floor.